The Bifocal Lens Inhibition of Myopia Progression (BLIMP) Study

THESIS

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By

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Abstract

The Bifocal Lens Inhibition of Myopia Progression (BLIMP) Study is a two year study comparing the progression of myopia in forty children ages eight to eleven fit in bifocal soft contact lenses to age- and gender-matched children fit in spherical soft contact lenses in the Adolescent and Child Health Initiative to Encourage Vision Empowerment (ACHIEVE) Study. Few studies have explored bifocal soft contact lenses for myopia progression inhibition, and no full studies have been published in peer-reviewed publications. This thesis only includes the one year data of twenty eight children, and all data are confidential.

Distance center bifocal soft contact lenses are being used in this study. This is to allow accurate focus of light on the fovea for clear vision while providing peripheral retinal myopic blur that animal studies have shown to change eye growth patterns. Refractive quality of life assessment took place before subjects were fit in contacts and at every follow-up visit. Their refractive quality of life improved and was equivalent to that of children fit in spherical soft contact lenses in the ACHIEVE Study. Previous studies have explored lined bifocal spectacles, no-line bifocal spectacle lenses, and bifocal soft contact lenses as myopia progression inhibition methods assuming accommodative error or effort is part of what drives myopia progression.

We fit twenty eight pediatric subjects in bifocal soft contact lenses and followed them for a period of one year. We measured refractive and biometric data at baseline and
one year. The same data were measured in a historical control group of twenty-eight age- and gender-matched spherical soft contact lens wearers.

Our data suggest that the children fit in bifocal soft contact lenses had less increase in their myopia over a year than the children who wore single vision spectacles (SVLs). The average (±SD) rate of progression of the spherical equivalent refractive error of the soft bifocal contact lens subjects was -0.39 ± 0.53 D for the right eye and -0.40 ± 0.39 D for the left eye. The rate of progression of the spherical equivalent refractive error of the soft spherical contact lens subjects was -0.60 ± 0.32 D for the right eye and -0.54 ± 0.34 D for the left eye. These progressions were not significantly different (Student’s t-test, p = 0.08 and p = 0.15). The axial length data were not consistent with the refractive error data. The axial length of the soft bifocal contact lens subjects’ eyes increased by 0.18 ± 0.22 mm in the right eye and by 0.11 ± 0.23 mm in the left eye. The axial length of the soft spherical contact lens subjects’ eyes increased by 0.23 ± 0.17 mm in axial elongation of the right eye between soft bifocal and soft spherical contact lens wearers (Student’s t-test, p = 0.329), but the left eyes of the spherical soft contact lens wearers grew significantly more than the left eyes of the bifocal soft contact lens wearers (Student’s t-test, p = 0.004).

Our study has not found a significant decrease in progression of myopia in children fit in bifocal soft contact lenses at this sample size.
Dedication

This document is dedicated to memory of my mother, Janis Louise Armstrong Baker.
Acknowledgments

I have had a lot of help and support while completing this masters program. I could not have done it without my family, especially my wonderful husband Sean. I feel so lucky to have found a perfect partner. The newest addition to my family joined us in the middle of this process and has made my life so rich; Ciaran, I love you.

Professionally I have been lifted up by so many people, but especially by a few. Jeff, you have given me freedom and support in a wonderful mix. Mike, you have believed in me enough to trust me guiding your students and the future of our specialty. Karla, it has been both scary and exhilarating knowing someone of your talents and accomplishments believes such wonderful things of me.

I feel fortunate to be surrounded by such amazing people that encourage me to achieve such things.
Vita

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Fields of Study

Major Field: Vision Science
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Chapter 1: Introduction

1.1 Public Health Significance

The prevalence of myopia appears to be increasing, from 25% of the American population in 1971-1972 to 33% in 1999-2004 (Vitale, 2009). Specifically, the prevalence in 12 to 17 year olds increased from 24% to 34%. Older data indicate that about two percent of children entering school in the United States are myopic (Blum, 1959), and approximately 15% of people starting high school are myopic (Sperduto, 1983). Juvenile myopia has a typical onset around age 8 years, and it progresses until 15 or 16 years of age (Goss, 1983). Myopia progresses at an average rate of approximately 0.50 D per year (Oakley, 1975) during this time, so the years 8-15 are the prime period to attempt to slow the progression of myopia.

Controlling myopia is important for a number of reasons, ranging from cosmesis to serious health risks. Though not a health risk, the cosmesis and comfort of glasses is something that affects every myope. With higher prescriptions, the lenses are thicker and heavier. To decrease weight and hide the thick sides of the lenses, myopes are encouraged to pick small, round, plastic frames, so there are fewer frame and contact lens options for higher myopes. Another way for myopes to decrease weight and thickness of lenses is to get higher index material lenses, but then only full rim frames are an option. Contact lenses come in limited parameters and currently only 11 soft contact lenses are available in myopic powers greater than -12.00 D (Tyler’s Quarterly, December 2009).
Thinner spectacle lens materials and higher prescription soft contact lenses are also more expensive. Higher prescription contact lenses are also thicker and therefore allow less oxygen to the cornea, which can lead to vascularization of the cornea. People with high refractive error also have a lower vision-specific quality of life (Pesudovs, 2006 & Rose, 2000). Some examples of items on the QIRC questionnaire used in the 2006 study are the amount of trouble not being able to see when you wake up (eg, to go to the bathroom, look after a baby, see alarm clock); the amount of trouble your spectacles or contact lenses are when you wear them when using a gym/doing keep-fit classes/circuit training; and the amount of concern you have about becoming increasingly reliant on your spectacles or contact lenses (Pesudovs, 2006).

Poor refractive surgery outcomes are also more common in those with myopia greater than 6 D (Halliday, 1995). Furthermore, refractive surgery for extremely high myopia, the Intraocular Contact Lens, puts patients at higher risk of cataracts and retinal detachments.

Most seriously, high myopia puts people at higher risk of retinal detachments. Low myopes are four times more likely and moderate myopes are ten times more likely to develop a retinal detachment than hyperopes and emmetropes (The Eye Disease Case-Control Study Group, 1993). In fact 55% of non-traumatic retinal detachments are attributed to myopia (The Eye Disease Case-Control Study Group, 1993). Myopes are also at higher risk for glaucomatous loss in primary open angle glaucoma (Lee, 2008).
1.2 Can Children Wear Contact Lenses?

As previously stated, children typically become myopic at approximately eight years of age, but they have traditionally been fit with contact lenses at about 13 years. So, before considering the possibility of myopia control with soft bifocal contact lenses, it must be evident that children can wear contact lenses in general and soft bifocal contact lenses specifically.

Children have proven capable of inserting, removing, and caring for all modalities of contact lenses, including corneal reshaping (Cho, 2005, Walline, 2009), gas permeable (Grosvenor, 1989, Katz, 2003, Walline, 2001 & 2004), and soft contact lenses (Horner, 1999, Walline, 2004, 2007, 2007, 2008, 2009). The Contact Lenses in Pediatrics (CLIP) Study addressed the fact that many practitioners would not fit children in contacts before the age of 12 years, possibly because it would take too much time and therefore cost the doctors too much money. The study compared the chair time from initial fit into soft contact lenses through three months of follow-up care between 8- to 12-year-olds and 13- to 17-year-olds. The only difference in time was 15 more minutes of insertion and removal training required for the 8-12 year olds, which is normally conducted by trained optometric technicians, not doctors, so it does not affect the productivity of the office (Walline, 2007). In the same study, the quality of life improved similarly between children and teens (Walline, 2007). So children have been proven to be as easy to fit with contact lenses as teenagers who are routinely fit with contact lenses in the United States.
The Adolescent and Child Health Initiative to Encourage Vision Empowerment (ACHIEVE) Study was a three-year randomized clinical trial that looked at how contact lenses affected the self-perceptions of children between the ages of eight and 11 years. They found that children who were fit with contact lenses felt better about their appearance, athletic ability, and social acceptance (Walline, 2009). Therefore, children experience benefits of contact lens wear beyond vision correction. Contact lenses also boost self-esteem in areas that are particularly important to young myopic patients.

Children are also capable of wearing soft bifocal contact lenses in order to theoretically slow the progression of myopia (Aller, 2006, 2008 and Greiner, 2009). A quality of life survey based on refractive error, the Pediatric Refractive Error Profile (PREP), was developed for the Adolescent and Child Health Initiative to Encourage Vision Empowerment (ACHIEVE) Study (Walline, 2006, 2009) because no such survey existed for children. It was designed to be administered to children wearing either spectacles or contact lenses. There are two forms, one for each vision correction mentioned in the questions, items with ‘contact lenses’ in the question for contact lens wearers and items with ‘glasses’ in the question for spectacle wearers. PREP scores range from 0 (poor quality of life) to 100 (good quality of life). There are ten scales in the survey: overall vision, near vision, far vision, symptoms, appearance, satisfaction, activities, academics, handling, and peer perception. In work by Greiner, it was shown that there was no significant difference in PREP scores between eight to eleven year old myopes wearing spherical soft contact lenses in the ACHIEVE Study and bifocal soft contact lenses in the BLIMP Study (Greiner, 2009). Both groups of children experienced
overall increases in PREP scores when switched from spectacles to contact lenses, ranging from increases of 3 points to 35 points on a 100 point scale. Both groups saw a significant increase in satisfaction and activities scores (Greiner, 2009).

In summary, several studies have shown that children younger than 12 years are capable of wearing all types of contact lenses. Young children can independently insert, remove, and care for contact lenses. Young children also benefit from contact lens wear as much as teens without any additional short-term risks. Furthermore, when children are fit with contact lenses, they receive benefits beyond vision correction. They experience an improvement in their perception of their own appearance, athletic abilities, and peer interactions (Walline, 2009). Given all of this information, perhaps doctors will begin to assess a young patient’s ability to adapt to contact lens wear based on factors other than age alone, so younger patients will receive the treatment that is most appropriate for them.

1.3 Methods of Myopia Control

Several forms of myopia control exist. Pharmacological myopia control consists of anti-muscarinic agents such as atropine (Chua, 2006), cyclopentolate (Yen, 1989), and pirenzipine (Tan, 2005 and Siatkowski 2004, 2008). Each of these has been shown to successfully slow the progression of myopia; by 76% using atropine (Chua, 2006 and Yen, 1989), by 37% using cyclopentolate, and by 41-51% using pirenzipine (Tan, 2005 and Siatkowski 2004, 2008). Atropine and cyclopentolate are used to cause temporary paresis of ciliary muscle and therefore cause an inability to accommodate. Pirenzipine
has also been reported to cause an abnormality in accommodation in 41% of patients. Pirenzipine is not currently available on the market.

Contact lens myopia control, using gas permeable contact lenses was initially promising (Perrigin, 1990 and Khoo, 1999), but two recent randomized clinical trials determined that gas permeable contact lenses have no effect on the growth of the eye (Walline, 2004 and Katz, 2003), which represents the permanent treatment effect on myopia progression. Previous reports of myopia control did not account for transient changes in the corneal curvature the gas permeable lenses were causing.

Optical myopia control attempts to alter some aspect of the optical input that may affect eye growth, such as accommodative lag or peripheral refraction. Findings from these studies have produced mixed results.

Under correction has shown in two prospective studies to actually increase the progression of myopia (Chung, 2002, Adler, 2006). Myopic blur has been shown to slow myopic eye growth in animal models (Smith 1994), but the residual myopic blur in children undercorrected by approximately 0.50 to 0.75 D actually increased myopia progression for an unknown reason.

Bifocal spectacles are meant to reduce accommodative effort and error. The first studies examined the effects of lined bifocals, but as technology advanced the question has been examined again with no-line bifocals. Oakley did a retrospective records review in 1975 that showed those in +2 D adds had less than a 0.05D/year progression, most of the patients were coincidentally esophores (Oakley, 1975). Goss found a slower progression of myopia in esophores wearing bifocals (0.2 D/year) than those wearing
SVLs (0.41 D/year) (Goss, 1986). These retrospective studies have shown slowed myopia progression with bifocals. Some prospective studies have shown a slowing in progression. Leung found more of an effect with +2 adds than +1.5 adds, 0.57 D and 0.47 D less, respectively, than SVLs (Leung, 1999). Fulk found a difference of 0.2 D in progression between esrophores fit in bifocals and those fit in SVLs at 24 months, but the difference did not increase in the next 30 months of the study (Fulk, 2002). Therefore though a few prospective studies have shown a slowing in progression (Gwiazda, 2004), more have shown no slowing in progression with bifocals (Parssinen, 1989, Grosvenor, 1987, Fulk, 1996, Brown, 2002, Edwards, 2002). In one prospective study, a subgroup of subjects who wore no line bifocals and had a high lag of accommodation and esophoria at near exhibited a greater treatment effect, 0.33 D versus 0.07 D, than the entire sample (Gwiazda, 2003, 2004).

1.4 Soft Bifocal Contact Lenses and Peripheral Retinal Blur

Interest has shifted recently to the influence of the periphery on foveal refractive error. Emmetropization is affected by the eye’s imposed central refractive state (Norton, 1999, Smith, 1994, Wallman, 2004), but relative peripheral hyperopic defocus may alter central refractive development in monkeys as well (Smith, 2009). Previously it had been surmised that there was a localized response to optical blur (Diether, 1997), but this new study showed that even in the presence of clear central vision, peripheral defocus affected central refractive error development (Smith, 2009).

It has been proposed that bifocal/multifocal spectacles may have limited effectivity because children do not use the bifocal portion, even after training. Bifocal
soft contact lenses provide a reading addition without the child having to adjust their use of the correction.

Alternatively, the bifocal soft contact lenses may provide peripheral myopic defocus, which slows eye growth. It has been shown that overall hyperopic blur causes the eye to grow faster and myopic blur causes the eye to slow eye growth (Park, 2003). A combination of myopic blur and hyperopic blur typically results in slowing of eye growth because myopic blur is a much stronger signal for controlling eye growth (Zhu, 2003).

Spurred by the peripheral retina’s ability to influence the central refractive error, some studies have explored the use of corneal refractive lenses to give clear central vision and peripheral myopic blur to attempt to control myopia. In two separate studies, Cho and Walline found that axial and vitreous chamber elongation were significantly slower for subjects wearing corneal reshaping contact lenses than those wearing single vision spectacles or contact lenses (Cho, 2005 Walline, 2009). There are two current studies also examining the affects of orthokeratology lenses on myopia progression (Eiden, 2009, Santodomingo, 2009).

Orthokeratology contact lenses provide clear central vision while providing myopic defocus in the periphery (Charman, 2006). Soft bifocal contact lenses with a distance center provide similar topographic features as an orthokeratology contact lens (Figure 1.1). The flat central portion provides corrected myopic refractive error and clear vision while the midperipheral cornea (orthokeratology, left) or contact lens (soft bifocal, right) steepening may provide myopic defocus in the periphery, acting as a signal to perhaps slow eye growth.
Figure 1: Topographical maps of a post-corneal reshaping eye (left) and an eye wearing a soft bifocal contact lens with a distance center (right).

A case report of twins showed no change in prescription of the eyes in the twin wearing the bifocal soft contact lenses (twin A) in the first year. The twin wearing the spherical soft contact lenses (twin B) had a progression of myopia of 1.19 D in that same time. When switched to soft bifocal contact lenses, the twin who had been wearing spherical soft contact lenses became less myopic by 0.5 D (Aller, 2008). It seems unlikely that twin B became less myopic after being switched from spherical soft contact lenses to bifocal soft contact lenses, but it provides the first shred of evidence that soft bifocal contact lenses may slow myopia progression. Furthermore, axial length data were not available from the baseline visit.

A prospective one year randomized clinical trial that compared the difference in myopia progression of children with eso fixation disparities at near wearing bifocal soft contact lenses to correct their eso fixation disparity to children with eso fixation disparity
wearing spherical soft contact lenses. The investigators found that cyclopegic autorefractions and axial lengths were significantly different between the two groups, the bifocal soft contact lens group having less spherical equivalent progression, by 72%, and smaller increases in axial length, by 71% (Aller, 2006).

1.5 Purpose

Several theories regarding control of myopic eye growth have been attempted. The current theory suggests that the peripheral retina may provide a much stronger signal to control eye growth than previously thought possible. Orthokeratology contact lenses have been found to slow axial elongation by two independent studies, and the mechanism of treatment effect may be due to the peripheral myopia associated with orthokeratology correction. Soft bifocal contact lenses with a distance center have similar topographical features to orthokeratology, which may indicate similar myopic blur in the periphery. If so, the results of this study may be similar to a randomized clinical trial that indicates soft bifocal contact slow myopia progression. The purpose of this study is to see if the progression of myopia in children can be slowed by bifocal soft contact lenses.
Chapter 2: Methods

The Bifocal Lens Inhibition of Myopia Progression (BLIMP) Study is a two-year comparison of the myopic progression of eight to eleven year old children wearing either bifocal soft contact lenses or spherical soft contact lenses. This thesis only includes data from the first year of the study.

2.1 Human Subjects Protection

The study was approved by the Biomedical Sciences Institutional Review Board of The Ohio State University, and it adheres to the tenets of the Declaration of Helsinki. Parents provided informed consent, and children provided written assent after receiving information about the requirements of participation in the study.

2.2 Recruitment

Children were recruited from the clinics at The Ohio State University College of Optometry, from local schools, and from area private practices. Consecutive children with interest in the study were evaluated for inclusion. All children who met the entry criteria were enrolled in the study without prejudice related to age, gender, or any other criteria.
2.3 Eligibility

Eligibility was determined at the baseline visit, and was the same as the eligibility criteria for the control subjects who participated in the Adolescent and Child Health Initiative to Encourage Vision Empowerment (ACHIEVE) Study.

The maximum age was set at eleven years in order to capture myopic children during their prime years of progression throughout the two-year study (Goss, 1983). The minimum age was set at 8 years to maximize the likelihood that the child would be able to successfully adapt to soft contact lens wear.

At the beginning of the study, the spherical component of the non-cycloplegic manifest refraction had to be between -1.00 D and -6.00 D, inclusive. These criteria were selected because children less myopic than -1.00 D are less motivated to wear their contact lenses (Perrigin, 1990). Those with more the -6.00 D of myopia before age 11 are more likely have pathological myopia, which may have a different mechanism of progression than typical juvenile-onset myopia (Fredrick, 2002).

The participants had to have less than 1.00 D of astigmatism at enrollment because the lens they were fit in, the Proclear Multifocal is a spherical multifocal lens and would not provide good enough vision for those with one diopter or more astigmatism.

The requirement of best-corrected visual acuity was 20/20 or better in each eye to exclude children with amblyopia or other ocular abnormalities that may affect vision because of quality of life issues associated with decreased vision.
Subjects could not wear rigid contact lenses within the month previous to enrollment or participate in any other eye research during participation in BLIMP so that their progression of myopia would not be influenced by anything other than the current study methods.

Eligible subjects were also free of ocular or systemic health problems that could affect contact lens wear, such as dry eye, in order to maximize their ability to continue throughout the entire investigation.

2.4 Contact Lenses

Two contact lenses were used in this research. The bifocal soft contact lens used in the BLIMP Study was the Proclear Multifocal (CooperVision USA, Fairport, NY) distance center lens with a +2.00 D add. It is a monthly daily wear contact lens. It has a spherical central zone for distance vision and an aspheric annular zone for intermediate and near vision. It is made of omafilcon A and has a water content of 62%. It has an overall diameter of 14.4 mm, a base curve of 8.70 mm, a central zone of 2.3 mm, and a dk of 27. The spherical soft contact lens used the ACHIEVE Study was the 1-Day Acuvue (Vistakon, Jacksonville, FL). It is made of etafilcon A and has a water content of 58%. It has an overall diameter of 14.2 mm, a choice in base curves of either 8.5 or 9.0 mm, and a dk of 28.

2.5 Study Protocol

The BLIMP Study is a two-year clinical trial to assess whether soft bifocal contact lenses slow down progression of myopia. Visits for the study were conducted at baseline, one week, one month, six months, one year, eighteen months, and two years.
This report only includes data from the baseline and one-year visit because those were the only two visits that collected data to measure myopia progression.

Habitual visual acuities were measured at every visit using Bailey-Lovie charts illuminated at 70 to 120 cd/m². Best-corrected visual acuities were also measured at the baseline, one-year, and two-year visits, with the manifest refraction in a trial frame. All visual acuities were recorded monocularly and binocularly. Children read every letter in each line, beginning at the top of the chart, until three or more letters were missed on a line. The number of letters correct was recorded and converted to logMAR by subtracting the total number of letters correctly read from 54 and then multiplying by 0.02.

Binocular near visual acuities were measured at every visit as well. At the baseline examination, visual acuities were measured with the child’s habitual correction. At all subsequent visits, visual acuities were recorded while the child wore his or her contact lenses. Room illumination plus an overhead stand lamp illuminated the reduced logMAR chart at 40 cm. The procedure was the same as the distance visual acuities and scoring was standard for the reduced logMAR chart.

At baseline and during each annual visit, a manifest refraction was performed with a prism-dissociated blur balance. The power for the initial soft bifocal contact lenses was determined from the spherical equivalent of the manifest refraction performed at baseline. At all subsequent visits a spherical over-refraction was performed over the contact lenses, and the contact lens power was adjusted as needed.

The PREP was given to all subjects at all visits. At the baseline examination, subjects completed the PREP for Glasses, and at all subsequent visits they completed the
PREP for Contact Lenses. The PREP contains 26 items that comprise 10 scales and one overall score. Subjects read each item, then marked one of the following: “strongly disagree,” “disagree,” “neutral,” “agree,” or “strongly agree.” Each item was scored from one (negative feeling towards refractive error correction) to five (positive feeling towards refractive error correction), then scaled from zero (poor quality of life) to 100 (good quality of life) by subtracting one from the raw score and multiplying it by twenty five. If the child had questions about the words in the survey, examiners could only clarify meaning of words and not influence answers. Neutral was clarified as not agreeing or disagreeing. Results from the PREP are not reported in this investigation because they were reported in a previous thesis.

Axial length, cycloplegic central and peripheral autorefraction with and without contact lenses, and autokeratometry, were also performed at each baseline examination. Axial length and cycloplegic central autorefraction were repeated at annual visits. Axial length was measured on a Sonomed A-scan, model A-5500. Five measurements of each eye were taken; any that did not have high, distinct peaks were replaced with a new measurement. Cyclopegia was achieved with two drops of 1% tropicamide instilled in each eye five minutes apart. Central and peripheral autorefraction was performed with the Grand Seiko autorefractor. Peripheral autorefraction was taken at 10, 20 and 30 degrees from straight ahead in superior, inferior, temporal, and nasal directions. Central autorefraction was repeated ten times and peripheral autorefraction was repeated five times in each position of gaze.
Standard examination techniques were performed for medicolegal reasons, but they were not recorded in the database. Those measures include: slit lamp examination of anterior ocular structures, assessment of contact lens fit, biomicroscopy of the posterior segment with a 20 D and 78 D lens (at the baseline exam, one, and two year visits), assessment of ocular alignment by cover test, accommodation by push-up amplitudes, visual field by confrontations, pupillary reaction, extraocular muscle testing, intraocular pressure, and near point of convergence.

Demographic information was collected at the baseline visit from the parent or guardian of the subject through a questionnaire. This information included the child’s birthdate, gender, and race or ethnicity.

2.6 Matching

Subjects in the BLIMP Study were matched based on age and gender to subjects from the ACHIEVE Study. Eight and nine year-olds were matched to other eight and nine year-olds and ten and eleven year-olds were matched to other ten and eleven years olds. Equal numbers of males were matched in each of the two age groups as well.

2.7 Statistics

Data were recorded in a restricted access Microsoft Access file. All data were doubled entered and checked for accuracy. Data analysis was done using SPSS (v. 17.0). Student’s t-tests were performed to examine differences between continuous variables, and Chi-square tests examined differences between categorical variables. Multivariate linear regression testing was run to evaluate interactions between near phoria status, baseline refractive error, and change in refractive error.
Chapter 3: Results

Forty subjects were fit with soft bifocal contact lenses. Eight bifocal contact lens wearers dropped out before one year, and four have not completed their one-year BLIMP visit. The remaining 28 subjects were matched on age (8 and 9 versus 10 and 11 years) and gender to soft spherical contact lens wearers who participated in the ACHIEVE Study.

Three subjects dropped out after the baseline appointment, three subjects dropped out after the one month appointment and two subjects dropped out after the 6 month visit. Four subjects stopped returning phone calls and showing up for appointments, two subjects moved during the study, one subject was not able to insert contact lenses, and one subject’s parents were going through a divorce and they felt the study was too time consuming. A flow chart of subject withdrawals is presented in Figure 2.
Figure 2: A flow chart explaining when and why subjects withdrew from the BLIMP study. Forty subjects were enrolled. Four subjects are still enrolled in the study but have not completed the one year visit. Twenty-eight subjects are included in the analyses.
Of the twenty-eight subjects who completed the first year of the BLIMP and ACHIEVE Studies, 43% (n=12) were male. The average age in years (± SD) of the subjects was 10.8 ± 0.8 years for the bifocal contact lens wearers and 10.9 ± 0.9 years for the spherical contact lens wearers (p = 0.58). Half of the bifocal contact lens wearers were white and 10.7% were Hispanic, but all of the spherical contact lens wearers were white. Baseline demographic data are presented in Table 1.

<table>
<thead>
<tr>
<th></th>
<th>Bifocal (n = 28)</th>
<th>Spherical (n = 28)</th>
<th>p-value</th>
</tr>
</thead>
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<tr>
<td>Males (%)</td>
<td>12 (42.8)</td>
<td>12 (42.8)</td>
<td>p = 1.0</td>
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<td>Age (years)</td>
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<td>10.91 ± 0.88</td>
<td>p = 0.58</td>
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<td>8 years (%)</td>
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<td>9 years (%)</td>
<td>3 (10.7)</td>
<td>1 (3.6)</td>
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<td>14 (50.0)</td>
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<td>Race/Ethnicity (%)</td>
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<td>Black, not of Hispanic Origin</td>
<td>7 (25.0)</td>
<td>0 (0.0)</td>
<td></td>
</tr>
<tr>
<td>Hispanic</td>
<td>3 (10.7)</td>
<td>0 (0.0)</td>
<td></td>
</tr>
<tr>
<td>White, not of Hispanic Origin</td>
<td>14 (50.0)</td>
<td>28 (100.0)</td>
<td></td>
</tr>
<tr>
<td>Other or unknown</td>
<td>1 (3.6)</td>
<td>0 (0.0)</td>
<td></td>
</tr>
</tbody>
</table>

Table 1: Baseline demographic information for bifocal and spherical contact lens wearers. Categorical data are number (percentage), and continuous data are means ± standard deviations. P-values represent statistical comparisons between groups.
The mean spherical equivalent at baseline for the right eye of the bifocal contact lens wearers was \(-2.45 \pm 1.03\) D, and for the spherical contact lens wearers it was \(-2.29 \pm 0.98\) D (Student’s t-test, \(p = 0.56\)). The mean spherical equivalent at baseline for the left eye of the bifocal contact lens wearers was \(-2.47 \pm 1.13\) D, and it was \(-2.28 \pm 0.95\) for the spherical contact lens wearers (Student’s t-test, \(p = 0.49\)). The baseline axial length of the right eye of the bifocal contact lens wearers was \(24.38 \pm 0.94\) mm and \(24.29 \pm 0.94\) mm for the spherical contact lens wearers (Student’s t-test, \(p = 0.70\)). The baseline axial length of the left eye of the bifocal contact lens wearers was \(24.39 \pm 1.02\) mm, and it was \(24.26 \pm 0.92\) mm for the spherical contact lens wearers (Student’s t-test, \(p = 0.62\)). Baseline anterior chamber depth was statistically shorter for the bifocal contact lens wearers than the spherical contact lens wearers (Student’s t-test, \(p = 0.02\) for both eyes). Lens thickness and vitreous chamber depth were not significantly different for either eye between the bifocal and spherical contact lens wearers (Student’s t-test, \(p > 0.05\)). Baseline ocular information is presented in Table 2.
<table>
<thead>
<tr>
<th></th>
<th>Bifocal (n = 28)</th>
<th>Spherical (n = 28)</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spherical Equivalent OD (D)</td>
<td>-2.45 ± 1.03</td>
<td>-2.29 ± 0.98</td>
<td>p = 0.56</td>
</tr>
<tr>
<td>Spherical Equivalent OS (D)</td>
<td>-2.47 ± 1.13</td>
<td>-2.28 ± 0.95</td>
<td>p = 0.49</td>
</tr>
<tr>
<td>Axial Length OD (mm)</td>
<td>24.38 ± 0.94</td>
<td>24.29 ± 0.94</td>
<td>p = 0.70</td>
</tr>
<tr>
<td>Axial Length OS (mm)</td>
<td>24.39 ± 1.02</td>
<td>24.26 ± 0.92</td>
<td>p = 0.62</td>
</tr>
<tr>
<td>Anterior Chamber Depth OD (mm)</td>
<td>3.84 ± 0.30</td>
<td>4.01 ± 0.27</td>
<td>p = 0.02</td>
</tr>
<tr>
<td>Anterior Chamber Depth OS (mm)</td>
<td>3.83 ± 0.31</td>
<td>4.01 ± 0.26</td>
<td>p = 0.02</td>
</tr>
<tr>
<td>Lens Thickness OD (mm)</td>
<td>3.44 ± 0.20</td>
<td>3.38 ± 0.17</td>
<td>p = 0.19</td>
</tr>
<tr>
<td>Lens Thickness OS (mm)</td>
<td>3.43 ± 0.22</td>
<td>3.35 ± 0.16</td>
<td>p = 0.16</td>
</tr>
<tr>
<td>Vitreous Chamber Depth OD (mm)</td>
<td>17.11 ± 1.00</td>
<td>16.90 ± 0.88</td>
<td>p = 0.40</td>
</tr>
<tr>
<td>Vitreous Chamber Depth OS (mm)</td>
<td>17.14 ± 1.07</td>
<td>16.90 ± 0.89</td>
<td>p = 0.37</td>
</tr>
</tbody>
</table>

Table 2: Baseline ocular information for bifocal and spherical contact lens wearers. Data are means ± standard deviations. Student’s t-tests were performed to compare means between groups.

The change in spherical equivalent refractive error of the right eye of bifocal contact lens wearers was -0.39 ± 0.53 D, and for the spherical contact lens wearers it was -0.60 ± 0.32 D (Students t-test, p = 0.08). The change in spherical equivalent of the left eye of bifocal contact lens wearers was -0.40 ± 0.39 D, and for the spherical contact lens wearers it was -0.54 ± 0.34 D (Students t-test, p = 0.15). There weren’t any significant differences between the treatment groups for changes in J_0 or J_{45} (Student’s t-test, p > 0.05) except for J_0 in the right eye, which is not clinically meaningful (Student’s t-test, p = 0.02) (Table 3 and Figure 3).
Figure 3: Graph showing increase in power in diopters of M, J0, and J45 of each eye in both the BLIMP and ACHIEVE Studies.
<table>
<thead>
<tr>
<th></th>
<th>Bifocal</th>
<th>Spherical</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spherical Equivalent OD (D) ± SD</td>
<td>-0.39 ± 0.53</td>
<td>-0.60 ± 0.32</td>
<td>p = 0.08</td>
</tr>
<tr>
<td>Spherical Equivalent OS (D) ± SD</td>
<td>-0.40 ± 0.39</td>
<td>-0.54 ± 0.34</td>
<td>p = 0.15</td>
</tr>
<tr>
<td>J0 OD (D) ± SD</td>
<td>-0.12 ± 0.26</td>
<td>0.02 ± 0.16</td>
<td>p = 0.02</td>
</tr>
<tr>
<td>J0 OS (D) ± SD</td>
<td>-0.08 ± 0.20</td>
<td>-0.01 ± 0.17</td>
<td>p = 0.14</td>
</tr>
<tr>
<td>J45 OD (D) ± SD</td>
<td>-0.02 ± 0.17</td>
<td>-0.00 ± 0.17</td>
<td>p = 0.59</td>
</tr>
<tr>
<td>J45 OS (D) ± SD</td>
<td>0.01 ± 0.14</td>
<td>0.05 ± 0.15</td>
<td>p = 0.26</td>
</tr>
</tbody>
</table>

Table 3: Mean (±SD) one-year change in refractive error for the soft bifocal and soft spherical contact lens wearers.

Most of the changes in axial length, lens thickness, and vitreous chamber depth were not significantly different between the groups. However, the vitreous chamber depth and the axial length increased significantly more for the left eyes of the spherical soft contact lens wearers (Student’s t-test, p = 0.007 and 0.004) (Table 4 and Figure 4).
<table>
<thead>
<tr>
<th>Measurement</th>
<th>Bifocal</th>
<th>Spherical</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Axial Length OD (mm)</td>
<td>0.18 ± 0.21</td>
<td>0.23 ± 0.17</td>
<td>p = 0.33</td>
</tr>
<tr>
<td>Axial Length OS (mm)</td>
<td>0.11 ± 0.23</td>
<td>0.27 ± 0.16</td>
<td>p = 0.004</td>
</tr>
<tr>
<td>Anterior Chamber Depth OD (mm)</td>
<td>0.05 ± 0.12</td>
<td>0.01 ± 0.10</td>
<td>p = 0.21</td>
</tr>
<tr>
<td>Anterior Chamber Depth OS (mm)</td>
<td>0.02 ± 0.16</td>
<td>0.04 ± 0.17</td>
<td>p = 0.72</td>
</tr>
<tr>
<td>Lens Thickness OD (mm)</td>
<td>-0.03 ± 0.12</td>
<td>0.00 ± 0.09</td>
<td>p = 0.34</td>
</tr>
<tr>
<td>Lens Thickness OS (mm)</td>
<td>-0.01 ± 0.14</td>
<td>-0.02 ± 0.08</td>
<td>p = 0.77</td>
</tr>
<tr>
<td>Vitreous Chamber Depth OD (mm)</td>
<td>0.16 ± 0.18</td>
<td>0.22 ± 0.16</td>
<td>p = 0.21</td>
</tr>
<tr>
<td>Vitreous Chamber Depth OS (mm)</td>
<td>0.09 ± 0.23</td>
<td>0.25 ± 0.17</td>
<td>p = 0.007</td>
</tr>
</tbody>
</table>

Table 4: Change in oculometric measurements in one year in bifocal soft contact lens wearers and spherical soft contact lens wearers.
Figure 4: Graph showing increase in length of each ocular component of each eye in both bifocal soft contact lens wearers and spherical soft contact lens wearers.

The median near phoria of bifocal soft contact lens wearers was orthophoric. The change in refractive error was compared between those with near esophorias (n = 10) and those with near orthophoria or exophoria (n = 18). The baseline spherical equivalent in the right eye for ortho/exophores was -2.67 ± 0.99 D and for esophores was -1.87 ± 0.69 D (Students t-test, p = 0.03). The baseline spherical equivalent for the left eye of the ortho/exophores was -2.64 ± 1.17 D and for esophores was -2.01 ± 0.78 D (Students t-test, p = 0.15). Controlling for baseline spherical equivalent refractive error, the change in
spherical equivalent refractive error was not significantly different between the esophores and the ortho/exophores (Analysis of covariance, \( p = 0.54 \) & 0.24 for the right and left eyes respectively). The baseline data and change in refractive error in one year are presented in Table 5.

<table>
<thead>
<tr>
<th></th>
<th>Ortho- and Exophores N = 18</th>
<th>Esophores N = 10</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spherical Equivalent OD baseline (D)</td>
<td>-2.70</td>
<td>-1.86</td>
<td>p = 0.03</td>
</tr>
<tr>
<td>Spherical Equivalent OS baseline (D)</td>
<td>-2.64</td>
<td>-2.01</td>
<td>p = 0.15</td>
</tr>
<tr>
<td>Spherical Equivalent OD change (D)</td>
<td>-0.36</td>
<td>-0.41</td>
<td>p = 0.54</td>
</tr>
<tr>
<td>Spherical Equivalent OS change (D)</td>
<td>-0.33</td>
<td>-0.45</td>
<td>p = 0.24</td>
</tr>
</tbody>
</table>

Table 5: Comparison of baseline refractive data and refractive changes, controlled for baseline refractive error, in one year in esophores and exophores in bifocal soft contact lens wearers.

The baseline anterior chamber depth was significantly different between the groups. To explore if this difference affected the change in spherical equivalent refractive error, an analysis of covariance was conducted. When controlling for baseline anterior chamber depth, the change in spherical equivalent refractive error was not different
between the bifocal soft contact lens group and the spherical soft contact lens group (Analysis of covariance, $p = 0.05 \ & 0.09$, for the right and left eyes respectively).

Relative peripheral autorefraction was measured with and without bifocal soft contact lenses at the baseline visit to see how much, if any, non-central myopic blur the contact lenses create. For the bifocal soft contact lens condition the central refractive error is assumed to be 0 D and for the no contact lens condition, the subjects’ actual central autorefraction was used as reference. The no contact lens situation measured at an average 0.04 D of myopic blur over the three positions of gaze and the bifocal soft contact lens situation measured at an average of 0.88 D of myopic blur. Both situations showed the most myopic blur at 20 degrees and the least at 30 degrees. The data are presented in Table 6 and Figure 5.

<table>
<thead>
<tr>
<th></th>
<th>With Bifocal Contact Lenses</th>
<th>Without Contact Lenses</th>
<th>$p = \text{value}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>10° (D) ± SD</td>
<td>-0.89 ± 0.97</td>
<td>-0.01 ± 1.08</td>
<td>$p &lt;0.001$</td>
</tr>
<tr>
<td>20° (D) ± SD</td>
<td>-1.03 ± 1.26</td>
<td>-0.26 ± 1.20</td>
<td>$p = 0.001$</td>
</tr>
<tr>
<td>30° (D) ± SD</td>
<td>-0.71 ± 1.45</td>
<td>0.14 ± 1.20</td>
<td>$p = 0.002$</td>
</tr>
</tbody>
</table>

Table 6: Table comparing the relative peripheral refractive error of BLIMP subjects wearing bifocal soft contacts lenses and no contacts lenses (n=29).
Figure 5: Graph of relative peripheral refractive error of the peripheral refractive error in BLIMP subjects wearing bifocal soft contact lenses and no contact lenses.
Chapter 4: Discussion

The change in spherical equivalent refractive error over one year was not significantly different between spherical contact lens wearers and bifocal contact lens wearers (p = 0.08 OD and p = 0.15 OS). The increase in axial length in the right eye over one year was also not statistically different for spherical contact lens wearers and bifocal contact lens wearers (p = 0.33) but for the left eye, axial elongation was significantly greater for spherical contact lens wearers (0.27 ± 0.16 mm) than for bifocal contact lens wearers (0.11 ± 0.23 mm) (Student’s t-test, p = 0.004). Ultrasound measurement of the eye is less precise than autorefraction because of the way the measurement is taken. The target and instrument are fixed in autorefraction and only the target can be fixed in A-scan ultrasound. The change in axial length over one year did not show a significant difference between soft contact lens wearers (ACHIEVE) and bifocal soft contact lens wearers (BLIMP) (p = 0.33 OD and p = 0.004 OS).

When BLIMP data were analyzed to separate ortho- and exophores from esophores, no significant difference was found in their one year change in spherical equivalent when controlling for baseline spherical equivalent (p = 0.54 OD, p = 0.24 OS), however there was no soft contact lens wearers near phoria data to compare treatment effect with the bifocal soft contacts lens wearers.

We found a 31% slowing of myopia progression in our study and Aller found a 72% slowing of myopia progression in his study (Aller, 2006). We found a slowing of
axial length growth of 42% and Aller found a slowing of axial length growth of 71%. The correlation between the reduction in myopia progression and the slowing of axial lengthening in both studies are consistent with expected (Parssinen, 1993), in so much that the bulk of myopia progression is the axial lengthening. In his study Aller had slightly more myopic subjects at baseline and the inclusion age went up to 18 years, but the average age of his subjects was not published. Both age and amount of myopia affect the progression of myopia (Goss, 1983, Parssinen, 1993, Hyman, 2005), and though more advanced age would lead one to think myopia progression had slowed, his change over one year was still -0.78 D, so the fact that the subjects were more myopic at baseline may explain why he saw more of a treatment effect than we did. We also do not know the gender make-up of his study, and gender has been shown to affect progression (Parssinen, 1993, Hyman, 2005). Since we did not see an interaction between phoria status and treatment effect it seems unlikely that the eso fixation disparity of his subjects explains the difference in our treatment effects. Aller did prescribe different bifocal powers to different patients, so the individualized add powers may have influenced his treatment effect by giving different amounts of peripheral myopic blur.

There was not a statistically significant slowing of myopia progression in this study. With a sample size of 28 per group, we had 72% power to find a slowing of myopia progression by 50%, assuming the mean progression of the control sample (−0.60 D per year), standard deviations of progression according to the current samples (± 0.53 D for bifocal and ±0.32 D for spherical), and α = 0.05. If the 31% treatment effect continued over the 8 years that myopia progresses, the final refractive error would be
1.25 D less myopic, which some would argue is clinically meaningful. This treatment effect is less than with atropine and orthokeratology, comparable effectivity to pirenzipine, and more than reported for bifocals.

The fact that the phoria status was not significant and the overall treatment was marginally significant might suggest that the peripheral myopic blur induced by the bifocal soft contact lenses was more important than reduction in accommodative stress caused by the bifocal soft contact lenses. The relative peripheral error findings showed that though bifocal soft contact lenses induce more peripheral myopic blur than spherical soft contact lenses, they do not increase in peripheral myopia as much as one would expect, nor at the increasing rate you would expect. One would expect the peripheral myopia to increase linearly the way it does in orthokeratology since they have similar topographic profiles.

There are limitations to this study. Though our subjects are age- and gender-matched to their control counterparts, they were not randomized to their groups. The selection of matched subjects from the ACHIEVE Study could affect the significance of the treatment effect.

Approximately one-fifth of BLIMP subjects dropped out before their one year visit; this high withdraw rate could certainly affect our outcome. The subjects who dropped out could have been experiencing more peripheral blur and therefore were not motivated to continue; their myopia could have been progressing rapidly and felt the poor vision was because of the contacts, or they could have had large changes in near phoria status that made near work uncomfortable. Any of these complications could have
affected myopia progression. One year out of eight years of progression of myopia is only 16% of the overall development of myopia. The difference in myopia progression between these two groups could be all one would see over the eight years a typical myope progresses or it could be a snapshot of compounding progression inhibition, but a one year snapshot does not tell which it is.

The measurement of relative peripheral refractive error showed a much lower amount than would be expected. As light travels to the retina through a bifocal soft contact lens with a +2 add, one would expect more than 0.88 D of myopic blur. This result may point to the fact that either the manner in which we measured peripheral refractive error was not able to accurately measure it or that the bifocal soft contact lenses do not give the myopic blur to the peripheral retina that we believed they would.
Chapter 5: Conclusion

This study set out to find if bifocal soft contact lenses could be used to slow the progression of myopia compared to soft spherical contact lenses. While a difference of 0.18 D over one year may not seem clinically meaningful, a 31% slowing of myopia progression may approach clinically significant meaning if it continues to accrue over eight years. Assuming normal progression of 0.50 D per year, over seven years, myopia progression would be slowed by approximately 1.25 D. Whether or not this is clinically meaningful is debatable, but the information gained through this study may help lead to optimization of the optical signals that ultimately slow, stop or prevent myopia progression in children.
References


Greiner KL (2009) Quality of Life of Pediatric Bifocal Soft Contact Lens Wearers, Masters of Science Thesis; the Ohio State University, Columbus, OH.


